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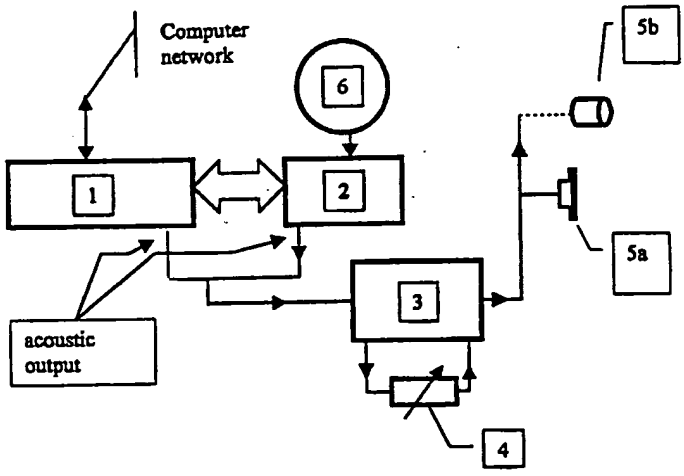
(54) Title: METHOD OF TESTING HEARING BY MEANS OF PERSONAL COMPUTERS



(57) Abstract

In the computer solution of the device for making audiometric measurements, a computer software controls the playback of test acoustic signals. The signals are saved on an optical, magnetic or magneto–optical disk or are uploaded from computer network. Following amplification the signals are received by the patient under examination. The characteristic feature of this solution is that the cirucits which feed acoustic signals to the patient's headphones or to the bone vibrator are plugged into the acoustic output of the disk drive or to another acoustic output of the computer or to the acoustic output of the computer which is connected via a computer network to a computer which reads the recording of the test signals. According to the invention, the computer audiometer can be operated manually or automatically. In the automatic mode, the computer software controls on its own the playback of test signals recorded on a disk. It does it by periodically changing the tracks being read. The tracks contain signals with successive measurement frequencies of various levels or speech–in–noise test signals. According to the invention, the audiometer can be calibrated using pre–registered deviations of the resultant gain characteristics of the wall audio channel.

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METHOD OF TESTING HEARING BY MEANS OF PERSONAL COMPUTERS.

Background of the invention

The invention is about the principle of operation of devices used for audiometric measurements on a personal computer. The objective of these measurements is to conduct a quick and credible assessment of the hearing sensitivity of individuals. The assessment is made on the basis of measuring the threshold characteristics of hearing sensitivity versus stimulating tone frequency, similarly as in the standard audiometric measurements. The invention solves the problem of making audiometric measurements easily accessible for the public by providing cost-effective solutions based on the software for testing hearing installed in local personal computers or in network servers.

Commonly known and used are numerous types of audiometers including those based on digital and microprocessor technology which are made as specialised measurement devices. Some of the designs of these devices have been patented. In particular, the inventions covered by patents offer some specific solutions to audiometric devices, such as the inductive sound volume attenuator described in Polish national patent description number 75 183 dated March 22, 1972 (P.154217), the system of the hearing aid coupler and audiometer applicator described in national patent description number 78 910 dated October 15, 1973 (P. 160 024), the special design of the non-contact amplification switch described in national patent description number 86 804 dated September 12, 1973 (P. 165 182) or the design of a high frequency tube-based system described in national patent description number 88 054 dated January 19, 1970. The next patent description number 95 023 dated May 22, 1976 (P. 175471) is of a single transistor system for switching the tone in the audiometer. The above solutions have not been applied to the audiometer covered in this patent description due to changes in audio technology which has moved from analogue to digital. As a result, the principles of designs and operation of audiometric measurement devices have changed, too. One of the patented digital technology designs is patent description number 128 078 dated April 29, 1989 (P. 223914). Described in it is a method in which the audiometric zero is set by a specialised digital system with a display and register which stores all measurement tone volumes. The system controls the attenuator of the measurement signal. It could be put to use in its role of audiometric zero controller, its design, however, does not meet the standards of today's technology which has evolved with computer technology progress.

A solution listed on the national patent description and one that is relatively closest to today's technology is the audiometer given in description number 154 402 dated March 20, 1989 (P. 267730). A disadvantage of the design is that it requires an additional analog-to-digital converter which provides the source of reference voltage for another analog-to-digital converter by which test signals are generated. The current advancement of methods for digital signal recording makes it possible to store the signals directly in the digital form on computer media. Also, their amplitudes and frequencies are accurate and highly stable. Therefore, there is no need to use designs with an additional converter connected to a source of model voltage, neither is it necessary to perform a computer synthesis of measurement signals as is the case of the quoted description.

Audiometer designs are the subject of a number of international patent descriptions, too. One known design is given in the American patent description number 4,109,106 dated August 22, 1978. In it tests are made using a speech signal recorded on a mechanical medium which is equipped with a special device for selecting the track with the recording. Described in the American patent number 4,515,169 dated May 7, 1985 is another design for making audiometric measurements using a delay (latency) of signals fed to both ears. American patent number 5,105,822 describes methods of high frequency audiometry based on the use of interference phenomena in the ear canal. These solutions are either technologically outdated or pertain to a different type of measurement methods unlike the tonal audiometry method which is employed in the design offered by the invention. Other designs that are known from foreign patent descriptions pertain to speech audiometry or audiometric measurements which are made using the method of evoked potentials and as such are in no direct connection to the subject matter of the invention.

Even though the audiometers known and manufactured today are quite well suited for the job they are required for, they are specialised devices manufactured in relatively small quantities which makes them costly and not commonly available. At the same time, due to the growing epidemiology of hearing impairments and the resulting demand for hearing loss prevention, audiometric testing needs to be done in schools, in local health centres and other health care and medical institutions as well as in workplaces exposed to noise risk. As the personal computer is becoming more and more common and given the fact that it has the capacity to read data recorded on optical, magnetic or magneto-optical media, it seems possible to increase the availability of audiometric tests using the method and system which are the subject of the invention. Another way to make audiometric tests more available is to allow the tests to be done via a computer networks, e.g. Internet network. In this case, a computer provided with the drive of the medium which stores measurement signals may also serve as audiometry signal network server. Thanks to this solution test signals can be played back by another computer provided with properly calibrated amplifier and headphones and connected to the server via a computer network. Therefore, the invention solves the problem of how to develop a new method of making audiometric measurements without having to use specialised diagnostic devices, called audiometers.

Disclosure of the Invention

In the computer solution of the device for making audiometric measurements, a computer software controls the playback of test acoustic signals. The signals are saved on an optical, magnetic or magneto-optical disk. Following amplification the signals are received by the patient under examination. The characteristic feature of this solution is that the circuits which feed acoustic signals to the patient's headphones or to the bone vibrator are plugged into the acoustic output of the disk drive or to another acoustic output of the computer or to the acoustic output of the computer which is connected via a computer network to the computer which stores the test signals.

According to the invention the computer audiometer can be operated manually or automatically. In the automatic mode the computer software controls on its own the playback of test signals recorded on a disk. It does it by periodically changing the tracks being read. The tracks contain signals with successive measurement frequencies of various levels for threshold audiometry or speech-in-noise signals for speech audiometry.

According to the invention the audiometer can be calibrated using pre-registered deviations of the acoustic chain resultant transfer characteristic. The way the calibration of the computer audiometric channel is done is that the total gain characteristic of the channel for acoustic signal playback is calibrated by setting the gain for a selected frequency in the amplifier connected to the acoustic output of the disk drive or to another acoustic output of the computer. During the calibration, deviations of the gain for all frequencies are measured. These deviations are stored on the computer disk and used for automatic adjustment of gain while playing-back the signals matching the particular acoustic frequencies. This is done to ensure identical levels of sound in the headphones or in the bone vibrator for all frequencies supported in the audiometric test. The output amplifier to which headphones or bone vibrator are connected may contain the voltmeter allowing operator to read-out the level of signals and to set the defined value of calibration voltage. This voltmeter can be also attached as an external device connected to the same output headphones or bone vibrator are connected to. The use of this voltmeter and the pre-recorded harmonic tone of a known level allow to calibrate easily the audio channel for the selected frequency. The gain deviations known for other frequencies make it possible to equalise automatically the audio channel in the whole exploited frequency band. The properly controlled amplitude of electric signals delivered to headphones or bone vibrator having known voltage pressure response characteristics allows to obtain the needed levels of acoustic signals by the patient. Consequently, the computer provided with audiometry software, audio output with level control and output voltmeter, and gain equalisation data set related to concrete type of used electroacoustic transducer may serve as an accurate audiometer device. Another way of calibration of it consists in playing-back special composed calibration signal. This signal consists in two tones of the same frequency differing in amplitudes. These amplitudes are selected in such a way that the first signal is set below the hearing threshold and the second one is supposed to be just noticeable, i.e. its amplitude is set to the above the hearing threshold value. A person with normal hearing should do the calibration by setting the gain of the output amplifier to such a value for which the first tone remains inaudible to this normally hearing person while the second tone becomes noticeable. The rest of the calibration and equalisation procedure is as above. The application of the voltmeter is no longer needed while exploiting this subjective calibration method.

Detailed Description of the Invention

The design of the audiometer according to the invention is explained in detail on the basis of an example of a block diagram of a PC (Personal Computer) based audiometer. According to the invention the system can be put to use on a CD-ROM drive. The CD-ROM drive is a component part of a typical PC and reads a CD-ROM disk with test signals for audiometric measurements recorded on it. The headphones output of a CD-ROM drive is plugged into the input of the amplifying system whose output signals are fed to the headphones or to the bone vibrator of a known voltage pressure response characteristic. The headphones are part of the audio channel. The gain is set in the amplifying system in the calibration process which is done according to the standards applicable to audiometric devices. The computer with the CD-ROM drive has a software which lets it playback CD-ROM tracks, record patients' responses and visualise the characteristics of the hearing threshold plotted versus the acoustic stimulus frequency.

The audiometric computer system is shown in Fig. 1. It consists of a personal computer **1** and a disk drive **2** coupled through its acoustic output with the acoustic amplifier **3**, with the gain calibrated through the control **4** and with an optional voltmeter. Headphones **5a** or a bone vibrator **5b** are plugged into the amplifier's output. The amplifier is an external

device or it can be a part of the drive circuitry or computer card circuitry playing back the audiometric signals. In the disk drive **2** is a disk **6** with test signals recorded on it used for audiometric measurements. The computer **1** has a software which helps to carry out audiometric measurements by controlling the readout of signals from the disk **6** and record patient's responses and visualise and also archive the results from the audiometric measurements. In this example of the computer audiometer, the acoustic amplifier **3** is made as a miniature electronic device and placed in the casing of the CD-ROM disk drive. In another design, the audiometric signals were recorded on the computer hard disk, while the acoustic amplifier input **3** with plugged in headphones **5a** or bone vibrator **5b** is a part of the acoustic output of the computer's audio card.

The following is a description of the operation of the computer audiometer as explained and illustrated. Before the audiometer is started for the first time, a software for audiometric measurements is installed. The software comes on a CD-ROM disk. The software includes a user interface for the operator to communicate with the computer audiometer plus a set of procedures to control the readout of acoustic signals recorded on the CD-ROM disk and some routines to produce diagrams on the screen showing the characteristics of the threshold hearing level versus the acoustic stimulus frequency. The computer audiometer software and test signals can be also uploaded from the computer network, e.g. Internet as an installation package. The next option is such that the audiometer software and test signals are installed in the remote server and the PC connected to the network is using this software without a necessity of its local installation.

The audiometric characteristics can be produced using above software. The hearing sensitivity characteristics from the measurements can be stored in the archives of the computer database for future reference and comparison with the audiometric characteristics of the same patient taken before or with other patients' audiometric characteristics. In the example of the software, two modes of conducting the measurements were used. In the first mode, a change of the frequency of the signal used in the measurements and its volume is controlled manually by the operator. In the second mode, these changes take place automatically.

The way it is done is that the successive tracks with test signals recordings are played back as they match the particular measurement frequencies. The order in this case follows the rising sound levels. Depending on the patient's individual hearing sensitivity, when the signal reaches that patient's hearing threshold level, the patient lets the operator know they have heard a sound in the headphones. At that point, this information is entered into the computer, for example by striking a key. At that moment, on the audiometric characteristics being plotted on a frequency versus level of sound scale, a point is marked matching the threshold hearing sensitivity for a stimulus of a given frequency. Next, the stimulus frequency is changed to another one and the tracks with recordings of acoustic signals are read. These match the acoustic signals of a new frequency. The signals are played back, as previously, following the order of the rising sound level. In this way, having completed the procedure for all the frequencies in the test, the result is the patient's audiometric characteristics displayed on the screen. It can then be moved to the archives in the programme's database or printed out on a printer connected to the computer. In this example, the software used the following frequencies of stimulus signals which are harmonic signals: 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, 8 kHz, 10 kHz. Each of the signals was recorded digitally on the disk with the following levels: -10 dB, -5 dB, 0 dB, 5 dB, 10 dB, 15 dB, 20 dB, 25 dB, 30 dB, 35 dB, 40 dB, 45 dB, 50 dB, 55 dB, 60 dB, 65 dB, 70 dB, 75 dB, 80 dB, 85 dB, 90 dB, 95 dB, 100 dB, 105 dB, 100 dB, 115 dB. This version has the additional option of masking the ear which is not being tested by playing back noise.

Fragments of the noise at various volumes ranging from 10 dB to 100 dB are also recorded on the disk with test signals.

The described audiometer software has also the option of testing hearing by speech-in-noise signals. This kind of tests is organised in such a way that noisy speech patterns (words) are played-back to the examined subject and this subject is asked to select a picture on the computer screen corresponding to the perceived word. The computer program counts accurate and wrong answers, calculates the statistics and on this basis provides the assessment of the subject's hearing ability.

In this version of the computer audiometer, calibration of the audiometric channel is made by setting the gain control **4** in the acoustic amplifier **3**, as in the picture. This is done when a signal at 0 dB level and for instance 1 kHz frequency is being played back from the disk. During the initial calibration the output of amplifier **3** is connected to the voltmeter, and the headphones of the computer audiometer are coupled with an artificial ear and acoustic analyser. Through the analyser, measurements of the level of acoustic pressure can be made. In the conditions described above gain controller **4** is set to ensure that the headphone produces acoustic pressure at a level that will match the audiometric zero. Next, the computer audiometer plays back signals recorded on the disk at the level of 0 dB which match the other measurement frequencies. In these conditions, the meter of the level of acoustic pressure coupled with the artificial ear may show values different from the audiometric zero which match the deviations resulting from the specific frequency characteristics of the signal channel and the headphones. In the design which is the subject of the invention, these deviations are compensated for. The way it is done is that the deviations from the audiometric zero which are measured for the particular frequencies different from 1 kHz, in the process of calibration will be recorded in the computer memory and then used for automatic equalisation of the transfer characteristics of the audiometric channel while the computer audiometer is being used. In automatic equalisation of the audiometer's transfer characteristics, the recorded value of the deviation matching a signal of a specific frequency is added to the level of the same frequency signal being played back by the computer audiometer.

In this way, provided the calibration procedure is repeated in specific time periods, it is possible to secure accuracy of the audiometric measurements made with a computer audiometer which is the subject of the invention described. In the above conditions it is sufficient that every-day calibration of the computer audiometer is done with the use of a simple LED (light emitting diode) bar scale voltmeter connected to the amplifier 3 output while the computer plays-back the calibration test tone. Also a person with normal hearing can do the calibration using a two-tone calibration signal recorded in the computer storage. The calibration is executed by setting the gain of the output amplifier to such a value for which the first tone remains inaudible to the normally hearing person and the second tone becomes just noticeable to this person.

Brief description of the drawing

Figure 1 is a block diagram depicting a computer system which may be utilised to do audiometry testing.

Claims

1. A computer audiometry testing method realised through software control of the playback of acoustic test signals saved on optical or magnetic or magneto-optical disk or received from the computer network, said signals after the amplification received by the patient under examination using headphones or bone vibrator plugged into the acoustic output of the disk drive or to another acoustic output of the computer or to the acoustic output of the computer which is connected via a computer network to a computer which reads stored test signals.

2. A computer audiometry method as claimed in claim 1, further including the automatic mode of operation of computer audiometer software controlling on its own the playback of test signals recorded on recording media or received from computer network by periodically changing the tracks being read containing signals with successive measurement frequencies of various levels or speech-in-noise test signals.

3. A method of calibration of computer-based audiometer, said method comprising the steps of:

initial calibration procedure which is done by setting the gain of acoustic channel of said computer-based audiometer for a selected frequency in the amplifier plugged into the acoustic output of the disk drive or to another acoustic output of the computer;

further calibration procedure organised in such a way that deviations of the gain of said acoustic channel for frequencies other than said selected frequency are measured and recorded in the computer storage and used for automatic adjustment of the gain while playing back the signals matching the particular acoustic frequencies;

subsequent calibration procedure of said computer-based audiometer which is done with the use of a voltmeter connected to the audio output while the computer plays-back the calibration test tone;

subjective calibration procedure of said computer-based audiometer performed by a normally hearing person setting said gain of acoustic channel of said computer-based audiometer in such a way that some tones played-back by said computer-based audiometer are not perceived by the person and some other tones played-back by said computer-based audiometer remain noticeable to the normally hearing person.

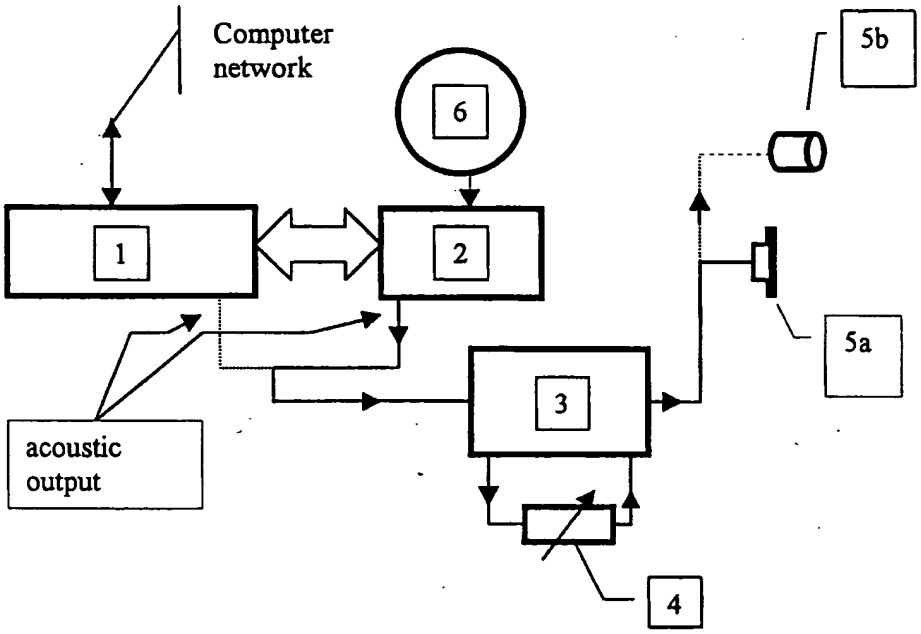

Fig. 1

INTERNATIONAL SEARCH REPORT

In ıtional Application No
PCT/PL 00/00019

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B5/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 105 822 A (STEVENS KENNETH N ET AL) 21 April 1992 (1992-04-21) cited in the application	1,2
A	column 5, line 36 - line 61 column 13, line 31 - line 46 column 17, line 38 -column 18, line 17	3
X	US 4 615 007 A (KING JAMES T ET AL) 30 September 1986 (1986-09-30)	1,2
A	column 4, line 32 -column 5, line 2 column 10, line 50 -column 11, line 15	3

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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3 July 2000	11/07/2000

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

In: ıtional Application No
PCT/PL 00/00019

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5105822 A	21-04-1992	NONE	
US 4615007 A	30-09-1986	NONE	